NATIONAL UNIVERSITY OF SINGAPORE

EE5703 – INDUSTRIAL DRIVES

(Semester 1 : AY2019/2020)

Time Allowed : 2 Hours

INSTRUCTIONS TO STUDENTS

1. Please write only your Student Number. Do not write your name.
2. This assessment paper contains **EIGHT** questions and comprises **FOUR** printed pages.
3. Students are required to answer **ALL** questions.
4. Students should write the answers for each question on a new page.
5. This is a CLOSED BOOK assessment.
6. Programmable calculators are permitted.
7. Total Marks is 60.

Q.1 For a modern variable speed electrical drive, briefly explain the following,

i. the benefits of variable speed drive over fixed speed drive
ii. the advantage of regenerative braking over dynamic braking
iii. the need of close loop cascaded control for the drive
iv. the relationship between drive specifications and load requirements
v. the key electrical EHM approaches for the drive

(5 marks)

Q.2 (a) A 200V, DC shunt machine has an armature resistance of 1Ω and field resistance of 200 Ω. The machine is running at 1000rpm as a motor drawing 31A from the supply mains. Calculate the speed at which the machine must be driven to achieve this as generator.

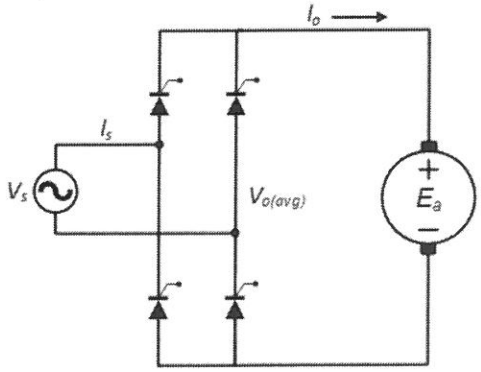
(3 marks)

Q.2 (b) A series motor is rated 100hp and 380V. The field winding and armature resistances are 0.068Ω and 0.072Ω, respectively. The voltage drop on the brushes is 3V total. At rated voltage, the motor operates with a speed of 675rpm when the motor current is 170A. For a copper loss (armature loss) of 1500W, calculate:

i. Motor speed
ii. Motor Current
iii. Motor input and output power
iv. Torque and
v. Efficiency.

(5 marks)

Q.2 (c) Explain electrical schematic in Figure Q.2(c) with regards to speed control of a DC motor. What is the effect of firing angle (α) on the direction of V_o, I_o, Power flow and direction of rotation? Also indicate which quadrants the motor operates in for different values of firing angle (α).



$$V_{o(avg)} = \frac{2V_m}{\pi}(\cos\alpha)$$

Figure Q.2(c) Schematic for DC motor control circuit

(2 marks)

Q.3 For a 10/8 Switched reluctance motor (SRM) drive,

i. Draw its electrical schematic using asymmetrical bridge converter.
ii. How many phases this SRM has? What is the step angle for this SRM?
iii. Explain magnetization, freewheeling and demagnetization modes using schematic in part 3(i).
iv. Briefly explain its fault tolerance as compared to an Induction Motor Drive.
v. How do we reverse the direction of rotation for this SRM drive?
vi. Comment on its ability to operate at high speed as compared to a PM Motor Drive.

(8 marks)

Q.4 (a) For a surface mount permanent magnet synchronous motor (PMSM),

i. Mention four key hard magnetic material used in the increasing order of their BH_{max}
ii. Briefly explain the purpose of soft magnetic material and banding material
iii. What is the effect of magnet thickness and temperature on the PMSM performance?
iv. Write key differences between a PMSM and a conventional synchronous motor.

(4 marks)

Q.4 (b) Write key differences between a PMDC and a BLDC drive comparing their construction, operating principle and performance.

(3 marks)

Q.5 (a) A 4-pole, 3-phase, 415V/50Hz Induction motor is supplied from 3-phase voltage source inverter and is controlled via open-loop V/f control. The motor speed is 1460 rpm when operated at rated load, supplied with 415V/50Hz. Neglect stator resistive drop in your calculations.

i. What will be the motor speed when operated at one fourth of rated load and 30 Hz?

ii. What should be the motor voltage and frequency if the starting torque needs to be two times the rated torque?

(4 marks)

Q.5 (b) Draw the block diagram of the direct torque control (DTC) method of an induction motor drive. Briefly explain the function of each block.

(6 marks)

Q.6 (a) Using block diagram and necessary equations, explain how space vector concept is used in permanent magnet synchronous motor (PMSM) for torque control.

(6 marks)

Q.6 (b) A 3-phase PMSM is controlled as a DC motor using stator current space vector so that the torque per ampere is highest.

Determine the phase current references i_a^*, i_b^*, i_c^* when rotor position is 30^0 away from the magnetic axis of a-phase winding and the motor torque is $5\ Nm$.

Use torque constant of $k_T = 1\frac{Nm}{A}$.

(4 marks)

Q.7 A 3-phase voltage source inverter with space vector based pulse with modulation (SV-PWM) is used in a 3-phase AC drive. Show the switching signal waveforms of the 3 legs of the inverter for one switching period, when the required phase voltages are $v_a = 193\ V\ , v_b = -52\ V, v_c = -141V$. Assume the DC link voltage is 600V.

(5 marks)

Q.8 Discuss how various types of stepping control are done in Stepper motor.

(5 marks)

END OF PAPER